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Introduction

The pbar facility shielding was previously reviewed in detail in 1991. In preparation for Collider Run II, it is necessary to increase the hourly 120 GeV proton intensity on the pbar production target to meet Collider Run II goals. In addition, as a result of the implementation of the Code of Federal Regulations regarding Department of Energy Radiation Protection Programs, the laboratory requirements for control of ionizing radiation have changed. As a result of these two events, it has become necessary to reevaluate the pbar facility shielding requirements and other controls necessary for compliance with the Fermilab Radiological Control Manual.

Beam Power Requirements

The Collider Run II beam power requirements which are related to the pbar source are as follows:

1.8E16 protons per hour at 120 GeV on pbar production target/APO beam absorber

3.6E13 protons per hour at 8 GeV through the AP2 line

3.6E13 protons per hour at 8 GeV through the AP3 line

3.6E13 protons per hour at 8 GeV through the Accummulator, Debuncher, and D/A transfer line

8 GeV negative secondary beam including pbars through the AP2 line and Debuncher

Shielding Requirements

The shielding requirements for this 2000 assessment are based upon the so called "Cossairt Criteria" included as Attachment 4. This document contains the shielding requirements for 1 TeV beam in eleven categories defined by the 1991 version of the Fermilab Radiological Controls Manual (FRCM) [2]. When Attachment 4 was written, the content of Department of Energy Radiation Protection Programs were dictated by DOE Orders. DOE Radiation Protection Programs now must conform to the requirements of the Code of Federal Regulations, 10CFR835. As a result, one of the break points between the dose rate categories set in Attachment 4 has been changed to match the break points in Chapter 2 of the current FRCM (Attachment 6). In addition, the beam energy found in the pbar source is less than 1 TeV. As a consequence, scaling for energy and radiation dose rate is required to determine shielding dimensions. When energy and dose rate scaling is required, the method cited in Attachment 5 has been applied.

The shielding requirements given by Attachment 4 are based upon a magnet to tunnel ceiling distance of three feet. There are only a few instances in the pbar source in which the magnet to tunnel ceiling distance is actually three feet. In the Accumulator/Debuncher rings, the typical magnet to ceiling height is six feet. In the AP1, AP2, and AP3 lines, the magnet to ceiling height varies from 1.5 to 6 feet. As a consequence of this variation and because of the uncertainty in the scaling methodology to be used for various distances, we focused our attention on making direct measurements to determine the adequacy of shielding for much of the pbar source.

Example calculations for energy, magnet to ceiling distance, and dose rate scaling are given in Appendix 1.

Method of Assessment

The pbar source consists of the following parts: the AP1, AP2, and AP3 lines, the pbar target vault, the Debuncher, the Accumulator, and the D/A transfer line. In addition to the respective shielding berms, there are four service buildings, three emergency exit trunks, three air shafts, three elevator shafts, nine exit stairwells, and six drop hatches. For each region of the pbar source we consider the following:

1. beam intensity requirement
2. beam energy requirement
3. required posting
4. existing posting
5. required barriers
6. existing barriers
7. existing entry control
8. existing interlocked detectors and associated trip levels
9. existing type of occupancy
10. required shielding based on Attachment 4 or result of measurement
11. existing shielding
12. assumed or measured value of quality factor
13. shielding category
14. dose rate scaling factor adjustment for non-standard magnet to ceiling tunnel distance
15. statement regarding the adequacy of shielding and other protective measures

AP1 Line

F17 Lambertson to buried pipe region (AP1 station 0+00 to 1+35.6)

Beam Intensity: **1.8E16 p/h**	**Beam Energy:** 120 GeV	
Category: 3A		
Magnet to Ceiling Distance: 2 feet minimum	**Magnet to Surface Distance:** 22.5 feet at minimum	**Dose Rate Scaling Factor:** 2.25
Required Shielding: 19 feet	**Existing Shielding:** 20 feet minimum	**Status:** Meets Requirements
Required Posting: Radiation Area	**Existing Posting:** Radiation Area	**Status:** Meets Requirements
Required Barrier: **Not listed**	**Existing Barrier:** 4 foot high wire fence	**Status:** Meets Requirements
Entry Controls: RWP and RSO approval	**Occupancy:** minimal	**Normal Losses:** not measurable
Interlocked Detector Trip Level: Not Applicable	**Quality Factor:** Assumed to be 5	

Adequacy of the region: OK

Buried pipe region (AP1 station 1+35.6 to 2+10.05)

Beam Intensity: **1.8E16 p/h**	**Beam Energy:** 120 GeV	
Category: 3C		
Magnet to Ceiling Distance: Not Applicable	**Magnet to Surface Distance:** Not Applicable	**Dose Rate Scaling Factor:** Not Applicable
Required Shielding: 19.3 feet	**Existing Shielding:** 21 feet minimum	**Status:** Meets Requirements
Required Posting: Radiation Area	**Existing Posting:** Radiation Area	**Status:** Meets Requirements
Required Barrier: **Not listed**	**Existing Barrier:** 4 foot high wire fence	**Status:** Meets Requirements
Entry Controls: RWP and RSO approval	**Occupancy:** minimal	**Normal Losses:** not measurable
Interlocked Detector Trip Level: Not Applicable	**Quality Factor:** Assumed to be 5	

Adequacy of the region: OK

PreTarget Labyrinth (AP1 station 2+10.05)

Beam Intensity: **1.8E16 p/h**	**Beam Energy:** 120 GeV	
Category: Not Applicable		
Magnet to Ceiling Distance: Not Applicable	**Magnet to Surface Distance:** Not Applicable	**Dose Rate Scaling Factor:** Not Applicable
Required Shielding: Not Applicable	**Existing Shielding:** Not Applicable	**Status:**
Required Posting: Controlled Area	**Existing Posting:** Radiation Area	**Status:** Exceeds Requirements
Required Barrier: **Not listed**	**Existing Barrier:** Concrete structure with service door	**Status:** Meets Requirements
Entry Controls: AC4 key	**Occupancy:** minimal	**Normal Losses:** 4.5 mrem/hr
Interlocked Detector Trip Level: 10 mrem/hr	**Quality Factor:** Assumed to be 5	

Adequacy of the region: Trip level should be reduced to 5 mrem/hr and detector type should be changed to the integrating trip mode to prevent spurious/unnecessary trips. Posting on the AP1 labyrinth entrance should be changed to Controlled Area if detector trip level is reduced to 5 mrem/hr.

PreTarget and PreVault region (AP1 station 2+10.05 to 5+22)

Beam Intensity: **1.8E16 p/h**	**Beam Energy:** 120 GeV	
Category: 3A		
Magnet to Ceiling Distance: 1.6 feet minimum	**Magnet to Surface Distance:** 21.6 feet at minimum	**Dose Rate Scaling Factor:** 3.5
Required Shielding: 19 feet	**Existing Shielding:** 20 feet minimum	**Status:** Exceeds Requirements
Required Posting: Radiation Area	**Existing Posting:** Radiation Area	**Status:** Meets Requirements
Required Barrier: **Not listed**	**Existing Barrier:** 4 foot high wire fence	**Status:** Meets Requirements
Entry Controls: RWP and RSO approval	**Occupancy:** minimal	**Normal Losses:** not measurable
Interlocked Detector Trip Level: Not Applicable	**Quality Factor:** Assumed to be 5	

Adequacy of the region: OK

PreVault enclosure beneath AP0 service building (AP1 station 5+22 to 5+60)

A number of measurements were made in this region to characterize losses under normal and accident conditions:

8 GeV accident condition - beam lost on VT108

Beam was intentionally misteered using HT107 to lose beam on PQ8B, VT108, PQ9A, and PQ9B in order to create losses in the upstream end of the AP0 service building. The results of this measurement are shown in Figure 1. The maximum dose rate was 1.2 mrem/hr. Since the building is a posted Radiation Area with RWP and entry control procedures, no additional protective measures are required for this condition.

120 GeV accident condition - beam lost on VT108

Several accident conditions were created for the 120 GeV accident condition. The limiting aperture in the region is VT108. The beam pipe and qudrupole apertures are large enough so that beam enters the target vault before it can be extinguished on any component but VT108. All quadrupole power supplies in the AP1 line were turned off except M:Q101 to avoid quad steering. This was necessary in order to produce the worst case accident scenarios for the region. Beam was misteered with M:HV102 at three different currents. Then M:HV102 was set to its nominal current and M:V105 was adjusted to produce losses in the upstream end of the building. The results of these four measurements normalized for a continuous beam loss are shown in Figure 2. From Figure 2, we see that an interlocked detector placed just downstream of VT108 would be optimally placed for mis-steering accidents with M:HV102. The same detector measured 78% of the peak dose rate measured for mis-steering accidents with M:V105. An interlocked detector set at 10 mrem/hr in the integrating mode would limits accidental dose rate for M:V105 mis-steering to 12.8 mrem/hr. Since the building is a posted Radiation Area with RWP and entry control procedures, no additional protective measures are required for this condition.

120 GeV normal conditions – stacking

Normal conditions during pbar stacking was characterized through a series of measurements. An interlocked detector was placed just upstream of the AP0 Vault as a result of the 1991 assessment. It has been set with a Quality Factor of 5 and a trip level of 10 mrem/hr. Based upon prior knowledge of the Quality Factor measurements made in the AP0 Vault, it was suspected that the Quality Factor at this location might be unity. A measurement was made with the help of the ES&H Section in which it was confirmed that the Quality Factor at this location is 1. The measurement result is included in Figure 4 and the Quality Factor result is presented in Attachment 1. A transverse measurement was also made across the upstream end of the vault to determine the shape of the distribution there. The result of the transverse measurement is shown in Figure 3. While the peak normal dose rate at the upstream end of the vault is 9 mrem/hr, it drops off very quickly with distance as shown in Figure 4. The practical dose rate to which personnel may be exposed will be much lower. Finally, to ensure that normal operation would not cause unnecessary rad trips, a measurement was made to determine the normal dose rate due to stacking at the location just downstream of the location where a new interlocked detector is proposed to be placed. The maximum normal dose rate is expected to be 1.3 mrem/hr. The result of this upstream measurement is also shown in Figure 4.

AP0 Service Building South Drop Hatch

There is a drop hatch in the AP0 Service Building which leads to the PreVault Enclosure. It contains about 10.5 feet of concrete shielding blocks. Since the hatch is not located directly above the beam lines, the effective shielding thickness exceeds 17 feet. A sketch of the drop hatch which was included in the 1991 assessment is included in this assessment as Attachment 11.

Adequacy of the region: Based upon the above measurements, the detector at the upstream end of the AP0 vault should be relocated to a position just downstream of VT108. The quality factor should remain at 5 with an integrating detector trip level setting of 10 mrem/hr. The FRCM would permit a higher trip level but it is felt that this limit will provide the necessary protection without interrupting normal operation. In short, the detector should simply be relocated about 24 feet upstream of it current position. . Since the building is a posted Radiation Area with RWP and entry control procedures, these protective measures are sufficient.

Vault Region

Vault region (AP1 station 5+60 to 5+71.46/AP2 station 0+00 to 0+25)

Beam Intensity: **1.8E16 p/h**	**Beam Energy:** 120 GeV	
Category: Normal losses are the worst case		
Magnet to Ceiling Distance: Not Applicable	**Magnet to Surface Distance:** Not Applicable	**Dose Rate Scaling Factor:** Not Applicable
Required Shielding: Not Applicable	**Existing Shielding:** Not Applicable	**Status:** Not Applicable
Required Posting: High Radiation Area	**Existing Posting:** High Radiation Area	**Status:** Meets Requirements
Required Barrier: **8 foot high rigid barriers with interlocked gates or doors and visible flashing lights**	**Existing Barrier:** 8 foot high, 3 foot thick concrete	**Status:** Does Not Meet Requirements
Entry Controls: RSO approval and RCT coverage; no beam on access	**Occupancy:** Exclusion area. No beam on access permitted.	**Normal Losses:** 190 mrem/hr
Interlocked Detector Trip Level: Not Applicable	**Quality Factor:** Based on earlier TLD measurements QF=1	

There are three other regions associated with the AP0 Vault where significant radiation exposure is possible. The AP0 Water Systems Cage within the AP0 Service Building contains the cooling water systems associated with the pbar Collection Lens, the Pulsed Magnet, and the AP0 beam absorber. The radiation levels found in this area occur due to gamma radiation emanating from the cooling water which contains the isotopes O15, N13, and C11 with half lives of 2 minutes, 10 minutes, and 20 minutes, respectively. The dose rates in the Water Systems Cage normalized to 1.8E16 protons per hour is about 1.6 R/hr [Reference 1].

An outdoor fenced-in area on the east side of the AP0 Service Building is also adjacent to the Water Systems Cage. The dose rates within this fenced area normalized to 1.8E16 p/h are as high as 125 mrem/hr. The results of the outdoor survey map are included as Attachment 7.

The roof of the AP0 service building is accessible via an outdoor caged ladder at the south end of the building. Dose rates on the roof have been measured previously and the results are included in Figure 21. The highest dose rate found on the roof normalized to 1.8E16 protons per hour is 35 mrem/hr. The average quality factor (QF = 1) can be deduced from the TLD data and that analysis is included in Figure 21.

Adequacy of the region: A Chipmunk is located within the water cage and provides audible and visible indication of excessive radiation levels. Interlocking the water cage and outdoor fence regions would not provide additional personnel protection because the radiation levels are due to activation of the water rather than prompt radiation. A Director's exemption was given as a result of the 1991 assessment to allow access to the vault and water cage to be controlled by the Area RSO. An appropriate shielding material will be added to the walls of the AP0 service building to reduce radiation levels in the outdoor fence region below 100 mrem/hr.

Finally, access to the roof of the AP0 service building is controlled in the same manner as access to the outdoor fenced area on the east side of AP0. These controls meet the requirements of the FRCM.

AP2 Line

Transport Enclosure beneath AP0 service building (AP2 station 0+25 to 1+00)

A series of measurements were made to characterize this region under normal and accident conditions. All beam energy associated with the region are 8 GeV or less. In addition, the quality factor of the region was measured.

Normal stacking losses

A series of measurements were made to map out the normal losses during pbar stacking operation. The results of these measurements are shown in Figure 5. It was determined that the losses associated with IQ1 and IQ2 are the worst case under normal conditions. We noted during accident condition studies for this region that radiation levels actually decrease when the tuning is not optimized through these quadrupoles. At IB1, however, we noted that dose rates are lower when tuning through IB1 is optimized for secondary transport. A Quality Factor measurement was also performed at the upstream most point and was found to be 5.0 [see Attachment 1]. The highest dose rate found was 22 mrem/hr but personnel access in that location is not likely. Dose rates in the regions where personnel access is likely range from 10 to 15 mrem/hr. While dose rates at this level are permitted by the FRCM in a posted Radiation Area for authorized personnel, some steps could be taken to minimize personnel exposure:

1. Include beam on exposure information in the AP0 RWP.
2. Install an alarming radiation detector in the region so personnel are aware when elevated radiation levels exist.
3. Designate this area of the service building for storage and equipment racks only.
4. Paint or otherwise mark the floor location where the elevated dose rates are expected to occur.

Accidental stacking losses

As noted above, the normal losses are the worst case for the region around IQ1 and IQ2. Accidental beam losses were studied on IB1 and the results are shown in Figure 6. The worst case accident radiation levels result when the secondary beam is lost in IB1. The peak dose rate under accident conditions is 42 mrem/hr when the Quality Factor of 5.0 is applied.

Accidental 8 GeV proton losses

A measurement for this accident case was made with forward protons into IB1. The results are shown in Figure 7. The worst case dose rate was found to be 7.1 mrem/hr using the measured Quality Factor of 5.0.

AP0 Service Building North Drop Hatch

There is a drop hatch in the AP0 Service Building which leads to the Transport Enclosure. It contains about 10.5 feet of concrete shielding blocks. Since the hatch is not located directly above the beam lines, the effective shielding thickness exceeds 15 feet. A sketch of the drop hatch which was included in the 1991 assessment is included in this assessment as Attachment 12.

Adequacy of the region: Since the AP0 Service Building is a posted radiation area which requires a key controlled by the MCR for access and a Radiation Work Permit, it meets the requirements of the FRCM without further modification. However, it would be prudent to take some measures as suggested above to ensure personnel who access the building are aware of real time radiological conditions.

Transport Enclosure (AP2 station 1+00 to 8+54)

The Transport Enclosure can be divided into five parts: AP0 Service Building to Left Bends, Left Bends, Left Bends to Indian Road, Indian Road, and Indian Road to AP50 Service Building. The first two sections were studied in some detail with direct measurements. The Indian Road region shielding was analyzed using Radiation Shielding drawings. Conclusions regarding the Left Bend to Indian road region can be drawn from the measurements made between the AP0 Vault and the downstream end of the Left Bends. Conclusions regarding the Indian Road to AP50 service building region can be drawn based upon a series of measurements made in the AP30 service building, the AP50 service building, and the AP20 earth berm. In addition, a special case is also considered where the MI8 enclosure passes beneath the Transport Enclosure.

AP0 Service Building to Left Bends (AP2 Station 1+00 to 5+05)

Beam optics for the AP2 line were studied to determine the most likely location at which normal and accident conditions could be studied upstream of the left bends. The problem is not straightforward because the line consists primarily of large aperture quadrupoles and large diameter beam tube which potentially makes it difficult to produce and measure a significant beam loss. IQ14 was chosen to represent this region of the Transport Enclosure.

Normal radiation levels during stacking at IQ14

Normal radiation levels due to secondary losses on IQ14 were measured over four different intervals within a 6.5 hour stacking period. The results of these measurements are show in Figure 8. The peak dose rate normalized to 1.8E16 protons per hour on target average at 0.09 mrem/hr. The signal to noise ratio for these measurements ranged from 0.007 to 0.04. Although this ratio is quite small, the ratio did not vary significantly on the individual detectors across the four measurements. This gives some level of confidence that the measurements are reproducible.

Accidental losses during stacking at IQ14

An attempt was made to measure the accident condition for secondary beam loss in IQ14. The signal to noise ratio was somewhat better than in the normal loss case ranging from 0.012 to 0.073. The result of this measurement is shown in Figure 9. The peak dose rate normalized to 1.8E16 protons per hour was found to be approximately 0.27 mrem/hr.

Accidental losses due to forward protons

8 GeV forward protons were steered into IQ14 to understand the shielding effectiveness of the Transport Enclosure berm. The signal to noise ratio in this measurement was much better (0.22 to 0.41) than that for either of the secondary loss conditions mentioned above because the total integrated intensity per unit time used in the study is larger than that which can be delivered by the secondary beam. The result of the study is shown in Figure 10. The peak dose rate measured and normalized to 3.6E13 protons per hour was 0.4 mrem/hr.

Adequacy of the region: The accident condition dose rates are less than 1 mrem/hr in these measurements assuming a Quality Factor of 5. No precautions are necessary.

Transport Enclosure shielding at MI8 line crossing (AP2 Station 4+00 to 4+40)

The MI8 enclosure passes beneath the Transport Enclosure in the region and is depicted in Figure 22. There is one special case in which personnel may be in the MI8 enclosure while it is possible for beam to be transferred through the Transport Enclosure. In this scenario, pbars or protons stored in the Accumulator. could be transferred to the AP0 vault and injected into the Main Injector. The beam would not survive in the Main Injector because the MI Coasting Beam Safety System would cause the beam to be lost immediately due to inserted beam valves caused by a personnel access in the MI8 line. This hazard is addressed in the MI shielding assessment. Here we consider, however, that the beam transferred from the Accumulator toward the AP0 vault is lost in the vicinity of the MI8 crossing point at IQ14. As shown in Figure 22, there is a foot of steel over a portion of the MI8 enclosure which was installed to protect the berm surface from losses originating in the MI8 line. This shielding was not designed for the special case considered here. While the steel shielding does cover most of the MI8 enclosure, the minimum earth shielding distance is 4.5 feet. Assuming a 100 mA transfer of 8 GeV pbars or protons from the Accumulator are all lost on IQ14, and considering the various scaling factors, the required minimum earth shielding is 4.2 feet. This entire scenario is possible but is thought to be very, very unlikely. It is considered here for completeness.

Beam Intensity: 100 mA or 1E12 pbars	**Beam Energy:** 8 GeV	
Category: 3A		
Magnet to Floor Distance: 6.5 feet	**Magnet to Surface Distance:** 11.5 feet	**Dose Rate Scaling Factor:** 0.46
Required Shielding: 3.8 feet	**Existing Shielding:** 4.5 feet minimum	**Status:** Exceeds Requirements
Required Posting: Radiation Area	**Existing Posting:** Radiation Area	**Status:** Meets Requirements
Required Barrier: **Not listed**	**Existing Barrier:** Various MI8 Enclosure Gates	**Status:** Meets Requirements
Entry Controls: RWP and key issued by MCR	**Occupancy:** minimal	**Normal Losses:** Not Applicable
Interlocked Detector Trip Level: Not Applicable	**Quality Factor:** Assumed to be 5	

Adequacy of the region: OK

Left bends (AP2 station 5+05 to 6+05)

The left bend region is unique. 8 GeV negative secondary particles including pbars, pions, kaons, muons and other exotics are momentum selected in the AP0 Vault by the pulsed magnet. Some pions and kaons decay in the drift space between the AP0 Vault and the left bends. The resulting off-momentum particles are lost in the left bends. The distribution of radiation levels on the berm surface over the left bends resulting from these normal losses was determined in this assessment. In addition, the accident cases of stacking with the left bends turned off and forward protons with the left bends turned off was investigated.

Normal radiation levels during stacking

A series of measurements were made over the left bends to determine radiation levels on the berm due to these normal losses. The results of the measurements are shown in Figure 11. I It is interesting to note the absence of any signal on the berm after IB5. We conclude that this is attributable to the beam converging while passing through the remaining two left bends. The peak dose rate found normalized to 1.8E16 protons per hour was 0.7 mrem/hr. A Quality Factor of 5 is assumed in the measurement.

Accidental losses during stacking

An accident condition was investigated in which the left bends were turned off to determine the radiation levels due to the secondary beam lost in the first left bend. The result of this measurement is shown in Figure 12. The peak dose rate measured and normalized to 1.8E16 protons per hour on target was 1.9 mrem/hr. A Quality Factor of 5 is assumed in the measurement.

Accidental losses due to forward protons

An accident condition was investigated in which the left bends were turned off to determine the radiation levels due to 8 GeV proton beam lost in the first left bend. The result of this measurement is shown in Figure 19. The peak dose rate measured and normalized to 3.6E13 protons per hour was 0.6 mrem/hr. A Quality Factor of 5 is assumed in the measurement.

Adequacy of the region: The region is a minimal occupancy area which needs to be posted as a Controlled Area. We considered the option of making a Quality Factor measurement on the region but concluded that even if the Quality Factor was 1, the resulting normal dose rates would still require the Controlled Area posting. For this reason, the measurement was not performed.

Left Bends to Indian Road (AP2 station 6+05 to 6+21)

This region has about 0.5 feet more shielding than the Left Bend region because the enclosure ceiling height is reduced while berm shielding continues at the same elevation. It is similar to the section of Transport between the AP0 Service Building and the Left Bends. A significant fraction of the off-momentum secondaries have been eliminated prior to reaching the section.

Adequacy of the region: Based on these factors and previous Transport Enclosure measurements listed above, no additional precautions are required.

Indian Road (AP2 station 6+21 to 6+80)

Steel shielding is used in Indian Road to compensate for the cut through the Transport Enclosure berm necessary to accommodate the road. Analysis of steel shielding, especially at the edges, can lead to improper conclusions about shielding adequacy in both conservative and non-conservative ways. To ensure a proper analysis of Indian Road steel, the method developed in the Main Injector Shielding Assessment was used [Reference 2]. A review of Radiation Safety Drawing 9-6-2-5 sheet C-3, Revision 3 reveals there are 5 different thicknesses of steel across the road. For the first region, it was necessary to determine whether a pipe or magnet in enclosure existed so that the appropriate Category could be determined. Figure 20 shows the region in question in which it is determined that pipe in enclosure is the proper category. A gage for each of the five regions was prepared to determine any inadequacies in the shielding. None were found. A copy of the gages used is included as Attachment 2.

Adequacy of the region: There are no inadequacies in this region.

Indian Road to AP50 Service Building (AP2 station 6+80 to 8+52)

The thickness of the shielding berm in this region is nominally 13 feet. No measurements were made in this region but the results of measurements made in several other regions can be applied. First, as will be shown below, the shielding effectiveness of the AP20 berm is a factor of a 100 better than the shielding in the AP30 service building. The berm between Indian Road and the AP50 Service Building is similar to the AP20 berm. Second, as will be shown below, the dose rate due to accidental loss of pbar stacking secondaries in the AP50 service building was found to be 42 mrem/hr. It may be concluded that the accidental loss of beam between Indian Road and the AP50 service building will result in a maximum dose rate of 0.42 mrem/hr.

Adequacy of the region: No precautions are required.

ACC/DEB service buildings

Shielding for the three Accumulator Debuncher service buildings has been considered. The shielding for each of the buildings consists of the concrete ceiling and service building floors and the intervening gravel backfill. The total shielding thickness in these service buildings is 10 feet. Shielding studies were performed in the AP10, AP30, and AP50 service buildings for this assessment. A quality factor measurement was made in the AP30 service building and is appropriate for all the service buildings since, for shielding purposes, the buildings are identical. Reverse protons were deliberately lost on the Accumulator Extraction Lambertson located beneath the AP30 service building to determine the peak radiation levels due to proton beam loss. A measurement was made in the AP50 service building to consider normal and accidental losses during stacking. A series of measurements were made in the AP10 service building to understand radiation peaks for some possible loss conditions there. Finally, the history of interlock detector trips was reviewed for these service buildings beginning in November 1994 to April 00 to reconsider detector placement. Historically, the service buildings have been posted as Radiation areas with the interlock detectors set to trip at 10 mrem/hr. The posting has recently been changed to Controlled Area. An analysis is included to propose a new interlock detector placement scheme to ensure that radiation levels appropriate for a Controlled Area are not exceeded.

AP30

A scale drawing of the AP30 service building is included as Figure 13. The drawing shows the location of the major beam line components such as bend magnets, quadrupole magnets, septa, and Lambertson magnets.

8 GeV Reverse protons were deliberately lost on the Accumulator Extraction Lambertson under AP30. The result of the study is shown in Figure 14. The peak radiation levels measured were about 24 mrem/hr normalized to 3.6E13 protons per hour. The full peak width at half of the maximum peak height is about 18 feet.

A Quality Factor measurement was also made at the AP30 service building at the peak of the loss over the Accumulator Extraction Lambertson. The Quality Factor was determined to be 5.7 by personnel from the ES&H Section [Attachment 3].

A history of radiation detector trips in the AP30 service building was compiled from the Operations Department Downtime Logger. The history includes only those detector trips which occurred due to radiation losses. It does not include trips due to failed detectors, loss of power to the detector, etc. The trips were then sorted by location. The resulting number of trips which have occurred from November 1994 to April 00 are indicated in red at each detector location in Figure 13. It is interesting to note that the detector trips tend to occur in the vicinity of the AP3 line. No trips were recorded over the Accumulator or Debuncher where the detectors are distant from the AP3 line. This suggests that recorded radiation detector trips are associated with the AP3 line and not the Accumulator or Debuncher.

Since the peak radiation level measured due to losses in the Accumulator Extraction Lambertson was 24 mrem/hr, it is clear that interlocked detectors are required to protect the buildings from excessive radiation levels.

There are 14 existing radiation detectors with seven evenly spaced over the Debuncher and seven spaced evenly over the Accumulator. The buildings are about 168 feet long excluding the 24 feet on each end dedicated to tunnel entrance stairwells and building accesses. The existing detector spacing is approximately 28 feet. Since the peak full width at half maximum was measured at about 18 feet, the existing arrangement could permit radiation levels to exceed 5 mrem/hr.

A four foot deep trench exists across the AP 30 service building which serves as a pipe chase for cryogenic systems serving the pbar source. As a consequence, the radiation shielding in this region is reduced to 6 feet. Two interlocked detectors are required here, one over the Accumulator and one over the Debuncher. The locations of these detectors are shown in Figure 13 and are described below.

We suggest that the fourteen existing detector locations be changed so that the detectors set over the AP3 line at roughly a 13 foot spacing. The trip level should be set at 2.5 mrem/hr with a quality factor of 5. The rad safety card would be of the integrating variety. The proposed array is indicated on the Figure 13 overlay. The placement of two detectors downstream of the Accumulator Extraction Lambertson is based upon the measured accident condition and would limit dose rates for normal and accident conditions to 5 mrem/hr. The worst case dose rates which could exist in the remainder of the building with a 13 foot spacing and considering an adjustment factor of 5.7/5 for the measured quality factor is 3.9 mrem/hr.

AP10

A scale drawing of the AP10 service building is included as Figure 15. The drawing shows the location of the major beam line components such as bend magnets, quadrupole magnets, septa, and Lambertson magnets.

A history of radiation detector trips in the AP10 service building was compiled from the Operations Department Downtime Logger. The history includes only those detector trips which occurred due to radiation losses. It does not include trips due to failed detectors, loss of power to the detector, etc. The trips were then sorted by location. The resulting number of trips which have occurred from November 1994 to April 00 are indicated in red at each detector location in Figure 15. It is interesting to note that the detector trips tend to occur in the vicinity of the D to A line (Debuncher to Accumulator transfer line). There are some locations under the AP10 service building where aperture restrictions due to instrumentation may cause beam loss. For reasons similar to those outlined in the AP30 service building section, we propose a new arrangement for the interlocked detectors in the AP10 service building. The new detector layout is based upon several peak measurements made for this assessment, a quality factor of 5.7 as measured at the AP30 service building, and is indicated on the Figure 15 overlay. The detectors would be set to 2.5 mrem/hr with a Quality Factor setting of 5. The rad safety card would be of the integrating variety. The normal and accident condition dose rates would be limited to 5 mrem/hr with the new detector layout.

AP50

A scale drawing of the AP50 service building is included as Figure 16. The drawing shows the location of the major beam line components such as bend magnets, quadrupole magnets, septa, and Lambertson magnets.

A history of radiation detector trips in the AP50 service building was compiled from the Operations Department Downtime Logger. The history includes only those detector trips which occurred due to radiation losses. It does not include trips due to failed detectors, loss of power to the detector, etc. The trips were then sorted by location. The resulting number of trips which have occurred from November 1994 to April 00 are indicated in red at each detector location in Figure 16. With two exceptions, the detector trips tend to occur over the AP2 line and Debuncher which functions as a continuation of the AP2 line in this service building. Two locations over the Accumulator have shown some interlocked detector trip activity which has been attributed to limiting-aperture, Accumulator instrumentation.

A study was done to examine the normal conditions for the injection region of the Debuncher. The distribution of normal losses is shown in Figure 17. The peak dose rates normalized to 1.8E16 protons per hour on target and assuming a Quality Factor of 5.7 is about 5.3 mrem/hr. A second study was done to examine the accident conditions for the injection region of the Debuncher. The accident was produced by turning off the injection septum. In addition, the vertical bend magnet power supply D:V730 was set at several currents in an attempt to move the loss peak. The results of this study are shown in Figure 17. The peak dose rate found normalized to 1.8E16 p/h and assuming a Quality Factor of 5.7 was 42 mrem/hr.

For reasons similar to those outlined in the AP30 service building section, we propose a new arrangement for the interlocked detectors in the AP50 service building. In this detector layout plan, we also cover the portion of the Accumulator where history shows that trips have occurred. Detectors should be set with a Quality Factor of 5 and a trip level of 2.5 mrem/hr. They should be equipped with integrating style of rad card. The detectors in the vicinity of the Debuncher Injection Lambertson are placed considering the studies conducted for normal and accident conditions. The remainder of the detectors are judiciously placed so that the peak dose rate for the normal and accident conditions for pbar injection normal and accident conditions would be limited to a dose rate of 5 mrem/hr. A Quality Factor of 5.7 is assumed in the analysis as was measured at the AP30 Service Building. The new detector layout is indicated on the Figure 16 overlay.

Adequacy of the region: The existing detector array, rad cards and trip levels could be used if the building is posted as a Radiation Area. However, a new detector layout with reduced trip level settings and integrating rad cards for each of the service buildings would permit use of the Controlled Area posting. If it is later found that the new detector scheme is too restrictive to permit reasonable operation of the pbar source, the trip levels, area postings, and entry controls for the building can be changed based on information presented in this assessment.

AP50 Pit

The salient features of the AP50 Pit region which have been examined are the detector alcove shielding, drop hatch shielding, exit stairwell, and the ventilation penetration. Sketches were produced from construction drawings to determine the shielding effectiveness of the detector alcove and drop hatch and are included as Figure 26.

A labyrinth calculation was made for the AP50 Pit exit stairwell and is included in Attachment 8. The resulting dose rate is less than 1 mrem/hr.

A labyrinth calculation was made for the AP50 Pit Ventilation Air Shaft and is included in Attachment 8. The resulting dose rate is less than 1 mrem/hr.

AP50 Pit Detector Alcove Shielding

Beam Intensity: **3.6 E13 p/h**	**Beam Energy:** 8 GeV	
Category: 2B		
Pipe to Ceiling Distance: 12.75 feet	**Pipe to Surface Distance:** 23.25 feet	**Dose Rate Scaling Factor:** 0.235
Required Shielding: 8.4 feet	**Existing Shielding:** 10.5 feet minimum	**Status:** Meets Requirements
Required Posting: Controlled Area	**Existing Posting:** Controlled Area	**Status:** Meets Requirements
Required Barrier: None	**Existing Barrier:** Service Building	**Status:** Meets Requirements
Entry Controls: None	**Occupancy:** unlimited	**Normal Losses:** not measurable
Interlocked Detector Trip Level: Not Applicable	**Quality Factor:** Assumed to be 5	

Adequacy of the region: OK

AP50 Pit Drop Hatch

Beam Intensity: **3.6E13 p/h**	**Beam Energy:** 8 GeV	
Category: 1A		
Magnet to Ceiling Distance: 3 feet	**Magnet to Surface Distance:** 25 feet at minimum	**Dose Rate Scaling Factor:** <1
Required Shielding: 13 feet	**Existing Shielding:** 14.5 feet minimum	**Status:** Meets Requirements
Required Posting: None	**Existing Posting:** None	**Status:** Meets Requirements
Required Barrier: **Not listed**	**Existing Barrier:** None	**Status:** Meets Requirements
Entry Controls: None	**Occupancy:** minimal	**Normal Losses:** not measurable
Interlocked Detector Trip Level: Not Applicable	**Quality Factor:** Assumed to be 5	

Adequacy of the region: OK

Accumulator/Debuncher berm

A measurement was made on the Accumulator/Debuncher berm at AP20 to check the adequacy of the shielding berm which is nominally 13 feet thick. An accident condition was created in which reverse protons were deliberately lost on the A2B7 magnet. The result of the measurement in shown in Figure 18. In addition, a Quality Factor measurement was made to determine the appropriate value to apply to the shielding berm. The Quality Factor was measured by ES&H Section personnel and was found to be 1 [Attachment 3]. The resulting peak dose rate on the berm normalized to a loss condition of 3.6E13 protons per hour is 0.26 mrem per hour.

It is interesting to note that this accident condition is similar to the one created at the Accumulator Extraction Lambertson. Using the measured peak dose rate at the two locations, one can conclude that the thirteen foot earth shielding berm is about 100 times more effective than the 10 foot gravel/concrete service building shielding. This factor was referred to earlier to make a conclusion on the effectiveness of the shielding between Indian Road and the AP50 service building for secondary beam loss.

There are three drop hatches associated with the Accumulator/Debuncher berm. An analysis done in the 1991 assessment showed that with 10 feet of shielding blocks, the straight-line shielding path was 12.88 feet. Since the drop hatches are filled with 10.5 feet of concrete shielding as described by supporting documentation from the 1991 shielding assessment, the shielding thickness is greater than 13 feet. This implies that the AP20, AP40, and AP60 drop hatches are shielded similarly to the remainder of the Accumulator/Debuncher berm. Copies of the appropriate documents are included in Attachment 10.

Adequacy of the region: No additional precautions are required for the Accumulator/Debuncher berm including the AP20, AP40, and AP60 drop hatches.

AP3 Line

The AP3 Line originates beneath the AP30 Service Building at the Accumulator Extraction Lambertson and terminates in the PreVault Enclosure where it rejoins the AP1 line. The AP3 Line shares enclosures with the AP2 line, AP1 or Accumulator/Debuncher except for the region between Indian Road and the AP30 Service Building. Shielding requirements which have been demonstrated to be met for the AP2 line also are sufficient for the AP3 line. In this section, the region in which the AP3 line does not share enclosures with other beam lines or the Accumulator/Debuncher is considered.

AP30 Service Building to Indian Road (AP3 Station 1+79 to 3+40)

This region is physically similar to the Indian Road to AP50 Service Building section of the AP2 line discussed earlier. The shielding is the same as that found in the Indian Road to AP50 Service Building section, but the beam power requirements are lower; the limiting case is 3.6E13 8 GeV protons per hour. Secondary beam loss scenarios do not apply to the region. Pbar transfers from the Accumulator toward the

Main Injector are of lower beam power than the above mentioned 8 GeV beam power limitation. In consideration of these factors, the region is adequate and no further precautions are necessary at this location.

Indian Road (AP3 Station 3+40 to 4+00)

The AP3 line crosses Indian Road and is shielded similarly to the AP2 line crossing as indicated on Radiation Safety Drawing 9-6-2-5. There is a single quadrupole, EQ11 beneath the road at AP3 Station 360. The drawing shows there are at least 13 feet of shielding present. There are no further precautions necessary at this location.

Labyrinths and Penetrations

Labyrinth calculations for this assessment were made using an Excel spreadsheet adapted from Reference 3. Where labyrinth calculations have been made for this assessment, they are included in Attachment 8.

There are three emergency exit trunks located in the Accumulator/Debuncher berm at locations AP20, AP40, and AP60. A labyrinth calculation made for this type of penetration for the accident condition at 8 GeV and 3.6E13 protons per hour. The resulting dose rate is less than 1 mrem/hr.

There are three air shafts located in the Accumulator/Debuncher berm at locations AP20, AP40, and AP60. A labyrinth calculation was made for this type of penetration for the accident condition at 8 GeV and 3.6E13 protons per hour. The resulting dose rate is less than 1 mrem/hr.

There are three elevator shafts located in the Accumulator/Debuncher service buildings at locations AP10, AP30, and AP50. A labyrinth calculation was made for this type of penetration for the accident condition at 8 GeV and 3.6E13 protons per hour. The resulting dose rate is less than 1 mrem/hr.

There are three exit stairwells referred to as type 1 stairwells in the Accumulator/Debuncher service buildings. Type 1 stairwells are located adjacent to the elevator shafts mentioned above. A labyrinth calculation was made for this type of penetration for the accident condition at 8 GeV and 3.6E13 protons per hour. The resulting dose rate is less than 1 mrem/hr.

There are three exit stairwells referred to as type 2 stairwells in the Accumulator/Debuncher service buildings. A labyrinth calculation was made for this type of penetration for the accident condition at 8 GeV and 3.6E13 protons per hour. The resulting dose rate is less than 1 mrem/hr.

There is one exit stairwell connecting the AP0 service building with the Transport Enclosure. A labyrinth calculation was made for this type of penetration for the accident condition. The resulting dose rate is less than 1 mrem/hr.

There are 5 sets of four 5 inch penetrations which run between the Transport Enclosure and the F27 service Building. A labyrinth calculation was made for this type of penetration for the accident condition. The resulting dose rate is less than 1 mrem/hr.

There is one exit stairwell connecting the AP0 service building with the Prevault. A labyrinth calculation was made for this type of penetration for the accident condition at 120 GeV and 1.8E16 protons per hour. The resulting dose rate is less than 1 mrem/hr.

There are about 440, five inch diameter penetrations in the AP10, AP30 and AP50 service buildings. There are five different types of penetrations which are shown in Attachment 9. The penetrations are indicated by type and location in Figures 23, 24, and 25 for Service Buildings AP10, AP30, and AP50 respectively. The type 4 penetrations are all located in the AP30 service building, were filled with polyethylene beads in the 1991 assessment, and do not warrant further consideration.

Individual analysis of the remaining penetrations would be extremely time consuming because the location of the penetrations with respect to beamline components varies. In addition, beam loss is not possible at every location because aperture restriction spacing is greater than the penetration spacing. Finally, many of the penetrations are filled or partially filled with cable, water pipes, or other utilities. We have chosen to make direct measurements of the effectiveness of the penetrations at some locations which represent the worst case scenarios.

A normal and accident condition was created in the AP50 service building to determine the relative response of radiation detectors placed over penetrations in the vicinity of the Debuncher injection septum and a detector placed at the peak location found in other Debuncher injection studies related to this assessment. The results of these studies are shown in Figure 25. The peak dose rates for both the normal and accident conditions occurred directly over the beam line components. The highest response found at the penetrations was 29% of that found at the peak location.

A normal and accident condition was created in the AP30 service building to determine the relative response of radiation detectors placed over penetrations in the vicinity of the Accumulator extraction Lambertson and detectors placed at proposed interlocked detector locations. The results of these studies are shown in Figure 24. The measurements in this case were made at one foot or less from the penetration exits. The peak dose rates for both the normal and accident conditions occurred at proposed interlocked detector locations rather than at the penetrations.

From the measurements at the AP50 and AP30 service buildings, we determine that the proposed interlocked detector arrangement discussed previously will provide adequate protection for penetrations in the Accumulator/Debuncher Service Buildings.

There are twenty-one site riser/survey penetrations in the pbar source. All site riser/survey penetrations were filled with polyethylene beads in the 1991 shielding assessment.

There is an 18 inch diameter penetration in the Accumulator/Debuncher 20-2 stub room. A labyrinth calculation was made for this type of penetration for the accident condition at 8 GeV and 3.6E13 protons per hour. The resulting dose rate is 40 mrem/hr. The construction drawings indicate that this penetration is filled with sand and therefore, no further protective measures are required.

There is an 18 inch diameter penetration in the Accumulator/Debuncher 10-2 stub room. A labyrinth calculation was made for this type of penetration for the accident condition at 8 GeV and 3.6E13 protons per hour. The resulting dose rate is less than 19 mrem/hr. There are several mitigating factors which can be considered which reduce the radiation dose rate to less than 1 mrem/hr. First, there are no massive devices such as quadrupoles or dipoles at the 10-2 stub opening which could produce significant large angle scattering of low energy neutrons. Materials that may be struck by the beam are a large aperture beam pipe, a DC Beam Current Transformer and a Gap Monitor. Second, an interlocked detector is proposed to be placed as shown in Figure 15 in the Southeast corner of the AP10 service building. The peak dose rates measured in a service building due to 8 GeV protons was found to be about 25 mrem/hr. With the interlocked detector trip setting at 2.5 mrem/hr, an addition protection factor of 10 can be applied reducing the dose rate at the exit of the penetration to 1.9 mrem/hr. Third, the penetration is not empty. It contains cryo piping which somewhat reduces the cross-sectional area of the penetration. Finally, the cryogenic piping rises above the ground in a way which prevents the possibility of personnel exposure directly in front of the penetration. On the basis of these mitigating factors, no further protective measures are necessary.

There is a four foot deep trench running across the AP30 service building floor with an 18 inch diameter penetration in the AP30 cyro room as depicted in Figure 24. Two interlocked detectors are to be placed across the trench area (one over the Accumulator and the second over the Debuncher) and will provide the necessary protection for this location.

There is an 18 inch diameter penetration in the Accumulator/Debuncher 40-1 stub room. A labyrinth calculation was made for this type of penetration for the accident condition at 8 GeV and 3.6E13 protons per hour. The resulting dose rate is 9 mrem/hr. The construction drawings indicate that this penetration is filled with sand which was verified by field inspection and therefore, no further protective measures are required.

There is an 18 inch diameter penetration in the Accumulator/Debuncher 50-1 stub room. A labyrinth calculation was made for this type of penetration for the accident condition at 8 GeV and 3.6E13 protons per hour. The resulting dose rate is 11 mrem/hr. There are a couple of mitigating factors which can be considered which reduce the radiation dose rate to less than 1 mrem/hr. First, there are no massive devices such as quadrupoles or dipoles at the 50-1 stub room opening which could produce significant large angle scattering of low energy neutrons. Materials that may be struck by the beam are a 4-8 GHz Core Momentum Kicker Tank and a large aperture beam pipe. Second, an interlocked detector is proposed to be placed as shown in Figure 16 over the Accumulator and just to the east of center of the AP50 service building. The peak dose rates measured in a service building due to 8 GeV protons was found to be about 25 mrem/hr. With the interlocked detector trip setting at 2.5 mrem/hr, an addition protection factor of 10 can be applied reducing the dose rate at the exit of the penetration to 1.1 mrem/hr. On the basis of these mitigating factors, no further protective measures should be necessary.

There is an 18 inch diameter penetration in the Accumulator/Debuncher 60-1 stub room. A labyrinth calculation was made for this type of penetration for the accident condition at 8 GeV and 3.6E13 protons per hour. The resulting dose rate is 8 mrem/hr. There are a couple of mitigating factors which can be considered which reduce the radiation dose rate to less than 1 mrem/hr. First, there are no massive devices such as quadrupoles or dipoles at the 60-1 stub room opening which could produce significant large angle scattering of low energy neutrons. Materials that may be struck by the beam are a 2-4 GHz Core Momentum Kicker Tank and a large aperture beam pipe. Second, the cryogenic piping rises above the ground in a way which prevents the possibility of personnel exposure directly in front of the penetration. Third, the stub room contains a fair amount of relay racks and equipment which would considerably increase the radiation attenuating effectiveness of the stub room. On the basis of these mitigating factors, no further protective measures should be necessary.

There are 5 sets of four 5 inch penetrations which run between the Transport Enclosure and the AP0 service Building. A labyrinth calculation was made for this type of penetration for the accident condition. The resulting dose rate is less than 1 mrem/hr.

There are 5 sets of four 5 inch penetrations which run between the PreVault Enclosure and the AP0 service Building. A labyrinth calculation was made for this type of penetration for the accident condition at 120 GeV and 1.8E16 protons per hour. The resulting dose rate is about 140 mrem/hr. The source of radiation loss for these penetrations would be VT108. Since an interlocked detector provides several orders of magnitude protection against the accident condition in this region, no further protective measures are required for these penetrations.

There are 5 sets of four 5 inch penetrations which run between the PreVault Enclosure and the F23 service Building. A labyrinth calculation was made for this type of penetration for the accident condition at 120 GeV and 1.8E16 protons per hour. The resulting dose rate is less than 1 mrem/hr. These penetrations have also been filled with poly beads. If it is desirable in the future to permanently remove the poly beads, the labyrinth calculation indicates that this is acceptable.

There are thirty-two 5 inch diameter penetrations which run from the vault region just above the target station modules to the floor of the AP0 service building. A labyrinth calculation was made for this type of penetration for the normal condition at 120 GeV and 1.8E16 protons per hour and considering a reduction in the source term by 6 orders of magnitude considering the attenuation through the steel modules. The resulting dose rate is less than 1 mrem/hr.

There are four 5 inch penetrations which run from the PreVault to the AP0 service building where sweeping magnet cables are to be run in the future. A labyrinth calculation was made for these penetrations for the accident condition of 1.8E16 protons per hour at 120 GeV. These penetrations enter the enclosure at a forward angle so that only back-scattered radiation may enter them. An adjustment was made in the labyrinth calculation to account for the geometry of these penetrations. The first foot of the penetration was treated as a first leg. The remainder of the first leg and the second leg were treated as second leg penetrations. The resulting dose rate is less than 2 mrem/hr.

There is a rigid 2 inch conduit in the floor adjacent to the sweeping magnet penetration. From a review of the construction drawings, it is apparent that this is a conduit which goes to a power panel at the south end of the AP0 service building. No further consideration is given to this penetration.

A 24 inch diameter air duct enters the floor at the North end of the AP0 service building and terminates in the Transport Labyrinth stairway. It is treated as a four leg penetration and was analyzed for the accident condition. The resulting dose rate is less than 1 mrem/hr.

There are four 5 inch penetrations at the North end of the AP0 service building used to carry various water pipes. These penetrations terminate in the northeast corner of the enclosure A labyrinth calculation was made for this type of penetration for the accident condition. An adjustment was made in the calculation to reduce the area of the penetration to account for the volume displaced by the water pipes. In addition, the first foot of the penetration was treated as leg 1 while the remainder of the penetration was treated as leg 2. The resulting dose rate was less than 1 mrem/hr.

There is an AP0 stack vent at the upstream end of the PreTarget Enclosure. The entrance to this penetration is located adjacent to the AP1 upstream stairwell previously discussed. Since attenuation through the stairwell is not as effective as through the vent stack piping and since the stairwell is protected by an interlocked detector, no further consideration of this penetration is required.

Summary

The pbar source shielding has been studied in detail. The following corrective actions are required before the new beam intensity limits listed at the beginning of this report may be applied. The position of the interlocked detector in the upstream end of the AP0 service building has already been changed. The remaining corrective actions are:

1. Post the left bend region of the AP2 line as a Controlled Area.
2. Reconfigure the interlocked detector arrangement in the AP10, AP30 and AP50 service buildings as described above. An alternative corrective action is to change the posting of the AP10, AP30, and AP50 service buildings to Radiation Area and implement any necessary entry controls which are deemed necessary. At this time, the pbar department prefers to adopt the new interlocked detector scheme. If at some time in the future it is determined that the interlocked detector scheme interferes excessively with pbar operations, the department may ask for a revised radiation detector trip levels and the Radiation Area postings. This can be accomplished on the basis of this shielding assessment document.
3. Repost the PreTarget upstream stairwell entrance as a Controlled Area. Change the trip level on the interlocked detector in the stairwell from 10 to 5 mrem/hr and change the rad detector card from the rate to an integrating card.
4. Add appropriate shielding material along the east wall of the AP0 service building to reduce normal radiation levels within the outdoor fence area adjacent to AP0 to levels below 100 mrem/hr.

References

1. Radiation Detector Characteristics While Stacking pbars in 1999, Pbar note 628, A.F. Leveling, February 24, 2000
2. Main Injector and Recycler Ring Shielding Assessment, MI Note 247, C. Bhat, September 1998
3. Approximate Technique for Estimating Labyrinth Attenuation of Accelerator-Produced Neutrons, Radiation Physics Note 118, D. Cossairt, September 1995